8. DEVELOPMENT, ANALYSIS, AND COMPARATIVE EVALUATION OF ALTERNATIVES FOR THE X-749/X-120 AREA

This chapter describes the development and analyses of groundwater remediation alternatives for the X-749/X-120 Area. Existing data are sufficient to support the development of groundwater remedial alternatives. The X-749/X-120 Area, surrounding units, and groundwater monitoring wells are shown in Figure 8.1.

8.1 X-749/X-120 AREA - GROUNDWATER RAOs

The RAOs for the X-749/X-120 Area groundwater are as follows:

- Achieve PRGs for groundwater when practicable.
- Prevent migration of COCs at concentrations exceeding PRGs (human health and ecological) from groundwater into surface water.
- Prevent exposure of future off-site residents to COCs in groundwater at concentrations exceeding residential PRGs.
- Prevent exposure of onsite personnel to COCs in groundwater at concentrations exceeding future onsite worker PRGs.

These RAOs are intended to prevent exposure of onsite workers to groundwater containing contaminants at concentrations exceeding PRGs (see Chapter 3, Section 3.1).

The contaminants of potential concern (COPCs) for groundwater in the X-749/X-120 Area include any chemical detected in groundwater during the RFI and subsequent sampling at concentrations exceeding analytical detection limits (Appendix A). The COPCs exceeding the screening criteria described in Chapter 3 were retained as COCs. TCE is the primary COC for groundwater at the X-749/X-120 Area. Tables 8.1 and 8.2 present the COCs and their PRGs for Gallia and Berea groundwater, respectively, in the X-749/X-120 Area.
Figure 8.1 The X-749/X-120 Area and Groundwater Plume

Table 8.1. Gallia Groundwater PRGs for Contaminants of Concern, X-749/X-120 Area

Contaminants of Concern	Gallia Groundwater PRG (μg/L)
Antimony *	36.5
Cadmium	6.5
Chromium	100
Cobalt	13
Lead *	50
Silver *	50
Thallium *	10.5
1,1,1-Trichloroethane	200
1,1,2,2-Tetrachloroethane	0.83
1,1,2-Trichloroethane	5
1,1-Dichloroethene	7
1,2,3-Trichloropropane	0.0379
1,2-Dibromo-3-chloropropane	0.2
1,2-Dichloroethane	5
1,2-Dichloroethene	900
Acrylonitrile	0.431
Benzene	5
Bromoform	100
Carbon Tetrachloride	5
Chloroform	100
Cis-1,2-Dichloroethene	70
Methylene Chloride	5
Tetrachloroethene	5
Trans-1,2-Dichloroethene	100
Trichloroethene (TCE)	5
Vinyl Chloride	2
1,4-Dioxane	25.9

PRG = preliminary remediation goal
μg/L = micrograms per liter
* Detected at one time at one location

Table 8.2. Berea Groundwater PRGs for Contaminants of Concern,

X-749/X-120 Area

Contaminants of Concern	Berea Groundwater PRG (µg/L)
1,1,2,2-Tetrachloroethane	0.83
1,2-Dichloroethane	5
Trichloroethene (TCE)	5
Vinyl Chloride	2

PRG = preliminary remediation goal
µg/L = micrograms per liter

Prior to 1998, most groundwater samples were collected using a bailer. The result was that many samples were turbid. Turbidity in samples was suspected of causing elevated concentrations of metals and radiological activity. Suspended solids, which are the primary cause of turbidity, result in possible bias in constituent concentration and activity because naturally occurring metals in the suspended solids are liberated during sample preservation. A comparison of metals and radiological parameters from samples derived using bailers and low-flow samplers is presented in DOE 1997 and DOE 1999. These studies found that metal concentrations and radiological activities decreased in more than 80% of the wells using the low-flow sampling method.

The studies have shown selected metals observed in groundwater at the X-749/X-120 Area at concentrations above PRGs were isolated. Metals concentrations, radiological activities, and associated distribution patterns do not indicate significant metals or radiological contamination in this area. Therefore, only metal results from wells sampled using low-flow techniques are included in the list of COCs presented in Appendix C.

8.2 DEVELOPMENT OF CONCEPTUAL MODEL AND VOLUME ESTIMATES

8.2.1 Conceptual Model Development

During Phase I of the Quadrant I RFI, groundwater samples were collected from 21 wells to characterize groundwater contamination in the X-120 Area. Because of closure activities, the X-749 Area was not investigated at that time.

During Phase II of the Quadrant I RFI, groundwater samples were collected from 67 wells to further characterize contamination in the X-749/X-120 Area. Semiannual groundwater sampling has been performed on 29 RCRA monitoring wells associated with the X-749/X-120 Area contaminant plume since 1991. Special groundwater sampling was also conducted during October and November 1997 to assess the potential for anaerobic biodegradation of contaminants and to define current plume conditions in the X-749/X-120 Area. Groundwater samples from 30 wells and 6 direct push technology (Geoprobe) samples were collected during this effort.

RFI data, data collected since the RFI, and plant operational knowledge were combined with historical lithologic data to produce a description of the hydrology, geology, and contaminant distribution for the X-749/X-120 Area. This information was incorporated into the numerical groundwater flow/solute transport model for evaluation of alternatives (Appendix E).

8.2.2 Vadose Zone Contamination in the X-749/X-120 Area

Contaminant data, summarized in Appendix A, for vadose zone soils (all soils above the water table, including deep soils) in the X-749/X-120 Area were screened to determine if potential continuing sources of groundwater contamination exist. Screened data is summarized in Appendix C.

The X-749 Contaminated Materials Disposal Facility (CMDF, see Figure 8.1) was used for the disposal of material contaminated with hazardous constituents and low-level radioactive waste. The landfill was divided into two areas, but is treated as a single unit in this CAS/CMS because a groundwater plume lies beneath both portions of the unit. The southern portion received nonhazardous low-level radioactive waste from 1986 through 1988 and was closed in accordance with RCRA Subtitle D requirements in March 1993. The northern portion received waste contaminated with solvents, oil, and wastewater treatment sludge from 1955 through 1989 and was closed in accordance with RCRA Subtitle C requirements in September 1993. The entire 11.5 acre landfill was covered with a multimedia cap, and barrier walls extending down to bedrock were installed on its northern and northwestern boundaries to inhibit the flow of groundwater beneath the unit. Subsurface groundwater drains, which also extend down to bedrock, were installed on a portion of the landfill's eastern and southwestern boundaries. These drains collect contaminated groundwater which is subsequently pumped to an activated carbon filtration system in the X-622 Groundwater Treatment Facility. The treated groundwater is then discharged pursuant to an NPDES permit.

The primary contaminant of concern in groundwater in the X-749 Area is TCE, which is believed to have been released during the landfill's operational life. While the primary release pathway to groundwater has been through soils that lie beneath the unit, the X-749 Landfill was capped in 1993 to prevent further leaching of contaminants from the vadose zone. The landfill is, therefore, not modeled as a continuing source of groundwater contamination.

The X-120 Goodyear Training Facility was located approximately 500 ft to the northwest of the X-749 Landfill (Figure 8.1) and housed a paint shop, a welding shop, and a sheet metal shop that were used to train plant personnel at PORTS. Two warehouses were also a part of this facility. All of the structures associated with the X-120 Goodyear Training Facility were demolished and removed in preparation for construction of the Gaseous Centrifuge Enrichment Plant (GCEP).

The groundwater beneath the X-120 Area is contaminated with TCE. While TCE may have been released to groundwater during the operational life of this facility, the area is not modeled as a continuing source of groundwater contamination because soil data for this area indicate TCE is not present at concentrations exceeding the soil leaching value of 48 µg/kg.

Construction of a horizontal well and the associated X-625 Groundwater Treatment Facility began in June 1995. The horizontal well was installed along the axis of the groundwater contaminant plume and is currently operational. A pilot project which employs reactive media to treat X-120 Area groundwater contaminated with chlorinated solvents became operational in March 1996.

The Peter Kiewit Landfill was operated from approximately 1953 until 1968. During plant construction, the landfill was used by the plant construction contractor, Peter Kiewit and Sons, as a salvage yard, burn pit, and trash disposal area. After plant construction, the landfill was used as a sanitary landfill.

Intermittent seeps containing vinyl chloride, discovered along the eastern boundary of the Peter Kiewit Landfill during the Quadrant I RFI, resulted in the relocation of a portion of Big Run Creek, installation of a seep collection system, and treatment of collected seep water at the X-622 Groundwater Treatment Facility. Additional seeps were discovered in a tributary of Big Run Creek on the southern slope of the Peter Kiewit Landfill in April 1997. An IRM trench was installed in the bed of the tributary to collect water from these seeps. A RCRA Subtitle D cap has been installed to prevent further infiltration of water into the landfill as part of the CMI activities for this unit. This cap was completed in the fall of 1998. The landfill is, therefore, not modeled as a continuing source of groundwater contamination.

A slurry wall was installed as an IRM along the PORTS property line to the south of the X-749/X-120 Area groundwater plume. The slurry wall, completed in September 1994, was installed to prevent contaminated groundwater from migrating off site.

8.2.3 Hydrogeology of the X-749/X-120 Area

The four primary geologic and hydraulic units that form the principal groundwater flow system at PORTS are, in descending order, the Minford, Gallia, Sunbury, and Berea. The Minford and Sunbury units exhibit relatively low hydraulic conductivities and are considered aquitards while the Gallia and Berea are water-bearing units where most groundwater flow occurs. The Minford is the uppermost unit at the site and consists primarily of silt and clay. The Gallia water-bearing unit lies directly beneath the Minford over most of the site and consists of sand and gravel. Below the Gallia is the lower permeability Sunbury Shale. The lower regional water-bearing unit is the Berea sandstone, which is of lower permeability than the Gallia. (Geraghty & Miller, Inc. 1994).

The primary source of groundwater recharge at the PORTS facility is precipitation. The amount of recharge varies for each area depending on the types and density of man-made surface features (buildings, paved areas, etc.) and the thickness of the surficial Minford clay. Recharge rates across the X-749/X-120 Area model domain range from 0.01 to 8.0 in. per year (SAIC 1997). Groundwater is removed from the local flow system by discharge to the bounding surface streams (i.e., Big Run Creek and the unnamed Southwest Drainage Ditch), the storm drain network, a horizontal well in the X-120 Area, groundwater collection trenches on the southwestern and eastern boundaries of the X-749 Landfill, and the Peter Kiewit Landfill seep collection trench.

In general, groundwater flows horizontally from north to south in the central portion of the X-749/X-120 Area toward the southern boundary of the site where it is impeded by the X-749 IRM Subsurface Barrier.

The hydraulic gradient is very low in this area because of the relatively flat valley floor and the presence of thicker and more permeable Gallia deposits. On the eastern and western boundaries of this area, groundwater gradients steepen and flow is toward Big Run Creek (east) and the unnamed southwest drainage ditch (west). Vertical gradients are downward from the Gallia to the Berea, except in the vicinity of Big Run Creek where gradients are locally upward.

Groundwater flow directions in the Berea are very similar to those observed in the Gallia. Flow is generally to the south in the central portion of the X-749/X-120 Area. To the east, groundwater flows toward Big Run Creek, while on the west flow is toward the unnamed southwest drainage ditch (Geraghty & Miller, Inc. 1994). Withdrawals at the various groundwater extraction points within the Gallia have little observable effect on flow patterns within the Berea.

Maps showing the effect each alternative has on the contaminant plume in the X-749/X-120 Area are presented in Section 8.5. Detailed descriptions of the geology and hydrology are presented in Section 1.4, Appendix E, and the Quadrant I RFI Draft Report (DOE 1994).

8.2.4 Groundwater Contaminant Distribution

The areal extent of the X-749/X-120 Area TCE groundwater plume as depicted for 1993 is based on data collected during the RFI (Figure 8.2). The extent of the TCE groundwater plume shown in Figure 8.3 is based on data collected in 1997 and 1998.

Data collected during the RFI and subsequent groundwater assessment monitoring indicate that the extent of groundwater contamination within the Gallia in the X-749/X-120 Area has been defined. The northern edge of the plume is marked by several wells where TCE has not been detected (X120-01G, X120-03G, X120-04G, and PK-10G). TCE contamination has migrated beneath the southwestern corner of the Peter Kiewit Landfill, but its eastern extent in this area is defined by a series of wells where little
Figure 8.2

Figure 8.3

or no contamination has been detected (PK-06G, X749-23G, X749-24G, X749-PZ01G, and X749-PZ02G). During 1997, VOC contamination was detected for the first time in wells X749-21G, X749-54B, and X749-BG7G. This new information indicates that the eastern lobe of the X-749 Area plume is migrating toward Big Run Creek. The southeastern and southwestern plume boundaries are also delineated by a series of wells (X749-44G, X749-68G, X749-PZ03G, X749-PZ05G, and X-749-PZ06G) where TCE has not been detected while the southern boundary is marked by the X-749 IRM Subsurface Barrier. TCE has not been detected in samples collected from monitoring wells immediately south of this subsurface barrier.

8.2.4.1 Natural Attenuation Study

Soil and groundwater sampling were conducted during October and November 1997 as part of a special study to screen for evidence of biological and other natural attenuation processes on chlorinated hydrocarbons in the X-749/X-120 Area. U.S. EPA defines natural attenuation as

> *the biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem (Kern, 1997).*

Although natural attenuation in the form of dispersion, dilution, and chemical stabilization are accounted for in the model simulations described in Appendix E, the effects of biodegradation were not considered due to lack of quantitative evidence of biological degradation. Data collected during this study, conducted in late 1997, were analyzed by using the scoring and screening process described by Wiedemeier (Wiedemeier et al. 1996) to evaluate the strength of evidence for anaerobic biological degradation. This scoring system evaluates the relative potential for anaerobic biological degradation on the basis of the following chemical and geochemical parameters: oxygen, nitrate, iron (II), sulfate, sulfide, methane, oxidation reduction potential, pH, DOC, temperature, carbon dioxide, alkalinity, chloride, TCE, dichloroethene, vinyl chloride, ethene/ethane, chloroethane, 1,1,1-trichloroethane, and 1,1-dichloroethene. Numerical scores are categorized into the following ranges: < 5 to 5, inadequate evidence for anaerobic biodegradation of chlorinated organics; 6 to 14, limited evidence for anaerobic biodegradation of chlorinated organics; 15 to 20, adequate evidence for anaerobic biodegradation of chlorinated organics; and > 20, strong evidence for anaerobic biodegradation of chlorinated organics.

Figure 8.4 shows the distribution of the individual well scores within the X-749/X-120 Area. The scoring sheets indicating parameters sampled, reason for sampling, criteria range, maximum possible score, resulting score for each parameter, and a total score for each well are contained in Appendix E as are assumptions used in scoring. The scores range from -3 to +10. The wells selected for sampling were chosen in order to provide a representative sample of the plume area. An attempt was made, when possible, to choose wells which intersect common flow lines up gradient and down gradient through the plume. Background wells (PK-08G, X120-03G, X120-10G, X749-24G, X749-44G, and X749-PZ06G) were chosen outside of the plume area to represent natural constituent conditions prior to the influence of anaerobic biodegradational activity. A review of historical TCE data indicates no trends or exceptionally noteworthy concentrations of degradation products.

In addition to scoring individual wells, the Chapelle (Chapelle et al. 1996), and the Buscheck & Alcantar (1995) methods were evaluated to determine if they could be used to estimate biological degradation rates. Both methods assume one-dimensional steady state transport of solute undergoing first-order biodegradation. TCE monitoring results from the X-749/X-120 Area suggest that the TCE plume has not achieved steady-state conditions. The installation of the X-749 Area barrier walls and trench in 1990 and 1991 have modified the local groundwater flow regime and it is likely that the area is still undergoing geochemical restabilization. Therefore, use of either of these two methods at the X-749/X-120 Area is inappropriate.

The data were also examined using the conservative tracer method in an attempt to calculate biological degradation rates. This method relies on the presence of a chemically nonreactive tracer in the contaminant plume. For chlorinated solvents, total chlorine (the sum of ionic chloride plus organic chlorine) is typically used as a tracer. This method is only effective if background chloride concentrations are relatively low compared to VOC concentration or if background concentrations can be factored out. An examination of the chloride data at X-749/X-120 Area reveals chloride concentrations that range from 1 to 100 mg/L which are orders of magnitude higher than that associated with VOC concentrations. In addition, the spatial variability in chloride concentrations prohibited factoring out background concentrations. This method also was not applicable.

Figure 8.4

As a final effort to estimate biodegradation rates, an attempt was made to model the data using BIOSCREEN (U.S. EPA, 1996). BIOSCREEN is a 1-dimensional analytical computer model used as a natural attenuation decision support system. A fundamental component needed to apply BIOSCREEN is selection of appropriate groundwater flow paths. One set of flow fields existed prior to implementation of the X-749 Landfill closure in 1990. The second set of flow fields used in this model simulation represents current conditions including closure of the X-749 Landfill. RCRA closure of the X-749 Landfill included installation of groundwater flow barriers on the north and west sides of the landfill, groundwater collection trenches on the east and southwest sides of the landfill, and a RCRA cap. These measures have significantly changed directions and magnitudes of groundwater flow and solute transport.

Seven potential flow paths were identified for use in BIOSCREEN in the pre-1991 flow field. All seven pre-1991 flow paths proved to be unacceptable for calibration targets due to the variability of data or an insufficient number of wells within the potential flow paths. Five potential flow paths were identified for use in BIOSCREEN in the post-1991 flow field. All five post-1991 flow paths proved to be unacceptable for calibration targets due to variability in data, and insufficient number of wells along the flow paths, and/or significant concentration changes over time. In addition, the post-1991 flow paths are suspect because of the changes in solute transport caused by the implementation of the X-749 RCRA closure action. As a result BIOSCREEN modeling could not be used to estimate biodegradation rates.

Given the inability to estimate biodegradation rates using Chapelle, Buscheck & Alcantar, and BIOSCREEN, and the low scores as a result of Wiedemeier screening, biodegradation rates were not used in the modeling simulations of alternatives. The modeling runs account for dispersion, dilution, and chemical stabilization only, and therefore, may underestimate the effects of natural attenuation.

8.2.5 Summary of the Conceptual Model

The primary source of groundwater in the X-749/X-120 Area is natural recharge from precipitation. The rate of recharge varies across the site as a result of surface development (i.e., buildings, parking lots, or open fields) and also as a result of the thickness of the surficial Minford clay aquitard. Groundwater flow beneath the X-749/X-120 Area is generally to the south and toward Big Run Creek. Highly compacted fill material west and south of the X-120 horizontal well acts as a barrier to plume migration. The hydrologic budget for this area has been described previously (Geraghty & Miller, Inc. 1990). The basis for modeling this area is further discussed in Appendix E.

8.2.6 Implications and Uncertainties

A comparison of metals and radiological parameters from samples derived using bailers and low-flow samplers is presented in DOE 1997 and DOE 1999. These studies found that metal concentrations and radiological activities decreased in more than 80% of the wells using the low-flow sampling method. The studies showed selected metals observed in groundwater at the X-749/X-120 Area at concentrations above PRGs were isolated. Metals concentrations, radiological activities, and associated distribution patterns do not indicate significant metals or radiological contamination in this area.

The thickness and permeability of the Gallia water-bearing zone in the X-749/X-120 Area have been demonstrated to be highly variable. Deposition of this unit took place in a fluvial environment, resulting in variation in the thickness and composition of the Gallia over relatively short distances. This variability was confirmed during installation and operation of the VER pilot project during the fall of 1998. Furthermore, the soil over much of the area was affected by pre-construction activities for the GCEP. These conditions lend an additional degree of uncertainty to predictions of groundwater flow and contaminant transport associated with specific well placement and may result in design changes during the CMI.

8.3 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section focuses on determining the best available technologies (BAT) applicable for remediation of contaminated groundwater in the X-749/X-120 Area by examining contaminated media and the effectiveness of the remedial technology. Table 8.3 presents the screening of technologies.

8.4 SELECTION OF REPRESENTATIVE PROCESS OPTIONS

Applicable remedial technology types or process options that were retained from the technology screening are evaluated for effectiveness, implementability, and cost. The evaluation determines which process options provide the best blend of these criteria at the conceptual level of investigation for each technology type. Representative process options are then used in the development of remedial alternatives. To simplify the process, one representative process option from each remedial technology type is selected for consideration in alternative development. Selection of a representative process option at this stage does not preclude the later use of an eliminated process option for detailed design and remedial action, if additional data or site conditions would later warrant such use.

Table 8.3. Groundwater Technology Screening, X-749/X-120 Area, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability	Retained/ Eliminated	Justification
				Groundwater		
No Action	None	Natural Attenuation	Processes such as dilution, dispersion, biodegradation, radioactive decay, or volatilization may naturally reduce the concentrations of some contaminants in some media.	All contaminants, all media	Retained	
Institutional Controls	Access and Use Restrictions	Physical Barriers	Fences, signs, or other barriers limit site access.	All contaminants, all media	Retained	
		Covenants/Deed Restrictions	Codes, deeds, or zoning restricts certain land uses.	All contaminants, all media	Retained	
		Industrial Requirements	Industrial policies and procedures (e.g., training, standard operating procedures, badges, guards) control employee access.	All contaminants, all media	Retained	
	Maintenance and Monitoring	Surveillance and Maintenance	Inspections of facilities and performance of preventive or corrective measures ensure proper operation of engineered controls.	All contaminants, all media	Retained	
		Monitoring	Sampling and characterization of waste, soils, surface water, groundwater, and air before, during, and after remediation verifies the effectiveness of remedial actions.	All contaminants, all media	Retained	
Containment	Hydrologic Control	Physical Barrier	Cutoff wall installed to bedrock surface to prevent contaminant migration	All contaminants, all media	Retained	
In Situ Treatment	Physical/Chemical Treatment	*Reactive Barriers/ Reactive Gates	A trench filled with appropriate reactive or sorbent material (e.g., granular activated carbon, ion exchange resin, or ceramic foam) can remove contaminants from groundwater flowing through the barrier. Process option includes DNAPL sorbents in trenches. Can also be combined with slurry walls.	All contaminants (with appropriate material) in shallow subsurface water	Eliminated	Not effective for achieving risk reduction to an acceptable range in all areas.
In Situ Treatment (continued)	Physical/Chemical Treatment	Air Sparging	Air injected into groundwater enhances volatilization. Coupled with collection and treatment of gases and condensate.	Volatiles in groundwater	Eliminated	Not effective in reducing VOC contamination in low permeability formations.

Table 8.3. Groundwater Technology Screening, X-749/X-120 Area, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability	Retained/ Eliminated	Justification
				Groundwater		
		Vertical Circulation Systems	Wells with screens near the bottom and top of a single aquifer can be operated to circulate water vertically in the aquifer and treat water within the well and possibly within the aquifer. Air-lift pumping and air stripping by using a blower and submersible pump can draw water into the well and strip VOCs from the water as air bubbles rise through the water column. Nutrients, oxygen, electron acceptors, and other soluble reagents can be added through the well to the groundwater within the aquifer to enhance bioremediation or other in situ treatment. Filters, bioreactors, catalysts, or other devices can be placed in the well for sorption or degradation of contaminants.	VOCs, nitrate, NAPLs, possibly other organic or inorganic contaminants in groundwater within the radius of influence of the circulation well	Eliminated	High levels of iron in groundwater can foul in well screens. Recirculation system may be used in conjunction with oxidant injection.
		Soil Flushing	Water, aqueous solutions, or acids are used to dissolve contaminants in the soil matrix. Contaminated elutriate is collected and pumped to the surface for removal or onsite treatment and reinjection.	Organics, Hg, other inorganics in soil	Eliminated	Not as effective in low permeability soils. Most effective when combined with soil excavation and media not contaminated with radionuclides.
		*Electrokinetics	Low-level direct current applied through electrodes in soil creates an acid front at the anode and mobilizes contaminants toward the cathode through the mass transfer mechanisms of advection, diffusion, and ion migration. Contaminants must then be removed, treated, and disposed.	Metals and some organic compounds	Eliminated	Not practical in highly industrialized setting. Not effectively demonstrated for all contaminants present.
In Situ Treatment (continued)	Physical/Chemical Treatment	*LASAGNA™	LASAGNA™ is a combination of treatment components that permits in situ treatment of contaminants by creating higher permeability soil environments. Used in concert with electrokinetics.	Metals and some organic compounds	Eliminated	Still in demonstration stage of development.
	Biological	Phytoremediation	Continuous passive treatment by use of vegetation to act as a pump for groundwater extraction and biological treatment. Also, limits surface recharge.	VOCs, certain SVOCs, and PCBs. Certain compounds can inhibit process	Retained	May be used in selected areas.
		Enhanced Bioremediation	Bacteria/algae are used for in situ conversion of compounds or to immobilize the contaminant.	Chlorinated compounds	Retained	

Table 8.3. Groundwater Technology Screening, X-749/X-120 Area, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability	Retained/ Eliminated	Justification
				Groundwater		
Ex Situ Treatment	Pump and Treat	Extraction wells	Contaminated groundwater can be pumped from an array of vertical, horizontal, or inclined well points, suction wells, ejector wells, or deep wells.	Contaminants that are miscible and move readily with water; inorganics	Retained	
		VER Process	A high vacuum (20 - 28 in. Hg) drawn through a well installed below the water table can strip volatile contaminants in groundwater and saturated and unsaturated soils from the aqueous phase into the vapor phase. Vapor-phase treatment (e.g., granular activated carbon) or other treatment systems can be included above ground. Typically used in combination with groundwater extraction.	VOCs in groundwater and soil. Effective in moderate to low permeability formations	Retained	
	Water Treatment Contaminant Removal/ Concentration	*Hydraulic Fracturing	Fracturing emplaces propped horizontal fractures on vertical spacings of approximately 1 in. Fractures serve as conduits for delivery of pressurized hot air or steam.	Contaminants in soil or water	Eliminated	Not practical because of existing facilities in industrialized area.
		Chemical Reduction/Oxidation	Contaminants are either destroyed or converted to more easily handled form by addition of oxidation agents (e.g., hydrogen peroxide, ozone, etc.) or reducing agents (e.g., ferrous sulfate, sulfur dioxide, etc.).	Metals, inorganics, organics, radionuclides	Retained	
Ex Situ Treatment (continued)	Water Treatment Contaminant Removal/ Concentration (continued)	Liquid Phase Adsorption	Water is pumped through a series of vessels containing sorbent to which contaminants are adsorbed. Potential adsorbents include granular activated carbon, Amersorb®, and sulfur-impregnated carbon. Granular Activated Carbon is a well-established, regenerable sorbent for VOCs. Amersorb® is a regenerable adsorption system with synthetic adsorbent 5 to 10 times capacity that of granular activated carbon.	VOCs in water, low concentrations of Hg in water	Retained	
		Air Stripping	Countercurrent mixing of large volumes of air with water to promote transfer of VOCs to air. VOC-contaminated water can be removed and stripped in an existing cooling tower onsite.	Volatiles (Henry's law constant > 0.003) in water	Retained	

Table 8.3. Groundwater Technology Screening, X-749/X-120 Area, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

General Response Action	Remedial Technology Type	Process Option	Description	General Contaminant and Site Applicability	Retained/ Eliminated	Justification
				Groundwater		
		Aerobic Biological Treatment	Aerobic biological wastewater treatment processes employ microorganisms, principally bacteria, that can use wastewater contaminants as part of their metabolism. The contaminants are thereby removed from the wastewater or transformed into a benign form. The primary mechanism of removal is oxidation with molecular oxygen serving as the oxidant or electron acceptor. The contaminant compounds serve as the electron donors and are typically referred to as substrates. The microorganisms obtain energy from mediating these redox reactions and use this energy to maintain cells and synthesize new cells or biomass.	VOCs	Eliminated	Not cost effective method for treatment of extracted groundwater. Retained as an in situ technology.

DNAPLs = Dense nonaqueous phase liquids
NAPLs = Nonaqueous phase liquids
PCBs = Polychlorinated biphenyls
SVOCs = Semivolatile organic compounds
TCE = Trichloroethene
VOCs = Volatile organic compounds
* = may be considered during CMI if additional data are available

Natural attenuation of contaminants by processes including dispersion, dilution, chemical adsorption or precipitation, natural biodegradation, and decay are likely occurring and will continue to occur regardless of the selected remediation strategy. The contributions of the different types of natural attenuation processes to the reduction or elimination of contamination are only partially evaluated for the selected process options.

8.4.1 No Action

The no action alternative serves as a baseline option and is retained to facilitate evaluation of the other active remedial measures. No Action includes natural attenuation, which may reduce contamination below PRGs in areas where levels of contamination are very low. No Action does not include monitoring, or operation and maintenance of existing remedial activities.

8.4.2 Institutional Controls

The purpose of institutional controls is to limit the likelihood of human or environmental exposure to media contaminated with COCs. Institutional controls include access and use restrictions and maintenance and monitoring activities. With proper implementation, institutional controls would be effective in reducing exposure to contaminated groundwater. All process options listed under institutional controls are readily implementable and costs are low compared with costs of other components in the developed alternatives.

8.4.3 Containment

Containment technologies are intended to prevent migration of contaminants. Barrier walls have been retained as an effective containment technology. The implementation of this technology is discussed further in Section 8.5.

8.4.4 In Situ Treatment

In situ remedial technology types are Physical/Chemical and Biological Treatment. Justification is given for eliminating technologies from further consideration in Table 8.3. Bioremediation and phytoremediation have been retained as in situ treatment technologies. This technology is discussed further

in Section 8.5. Technologies that have been eliminated due to difficulties associated with low permeabilities in the Gallia water-bearing unit in the X-749/X-120 Area may be considered during the CMI process.

8.4.5 Ex Situ Treatment

Ex situ remedial technologies are used to treat extracted contaminated groundwater and vapors from the subsurface and remove contaminants by using aboveground treatment facilities. Justification is given for eliminating technologies from further consideration in Table 8.3. Conventional groundwater pump and treat technology has been retained. These technologies, used both alone and in combination with in situ remedial technologies, have been evaluated for their effectiveness and are discussed further in Section 8.5.

8.5 DEVELOPMENT AND DETAILED ANALYSIS OF ALTERNATIVES

A comprehensive series of model simulations incorporating various remedial technologies, both alone and in combination, have been evaluated. These model simulations indicate that it is not practicable to move a sufficient quantity of water through the Gallia saturated zone to remediate groundwater and associated saturated soils to concentrations less than PRGs in all areas of the X-749/X-120 Area plume within the targeted 30-year time frame. Even with extensive application of best available technologies, the hydrogeologic conditions in this area preclude achieving the target risk level of 1×10^{-6} within 30 years. However, these simulations do indicate that groundwater contaminant levels can be reduced to an acceptable risk level of 1×10^{-5} in a much shorter time frame, in effect attaining the concentrations which are as low as reasonably achievable given the constraints of the local hydrogeologic system.

The alternatives selected employ the best available technologies for this area of the PORTS site. Alternatives were selected for their potential to meet RAOs, address all environmental problems, reduce overall risk to acceptable levels (1×10^{-4} to 1×10^{-6}), and protect human health and the environment. The no action alternative provides a baseline for comparison with active remedial measures. All alternatives, except for Alternative 1, include monitoring the effects of the remedial action chosen. The following are the remedial alternatives for groundwater at the X-749/X-120 Area.

C Alternative 1 - No Action

No actions are assumed for this alternative. No access and use restrictions or maintenance and monitoring are included.

C Alternative 2 - No Further Action

This alternative includes institutional controls and groundwater monitoring. Institutional controls include access and use restrictions, maintenance, and monitoring. This alternative includes continued operation of the existing X-120 horizontal well, the X-749 southwest and east trenches, and the Peter Kiewit collection trench.

C Alternative 3 - Pump and Treat

This alternative includes 34 extraction wells with treatment at an expanded X-625 Groundwater Treatment Facility. In areas of the plume where TCE concentrations are predicted to fall below 5 Fg/L, wells are turned off at the end of every 5-year interval to facilitate movement of the contaminated groundwater to the wells still in operation. The existing X-120 horizontal well, the Peter Kiewit trench and the southwest X-749 trench continue operation. A barrier wall is installed at the south end of X-749 Landfill and where the existing east X-749 trench is located, effectively containing contamination within this landfill. Monitoring and deed restrictions are also implemented in this alternative.

C Alternative 4 - Pump and Treat with Subsequent Phytoremediation

This alternative includes 34 extraction wells operated for 20 years with treatment of extracted groundwater at an expanded X-625 Groundwater Treatment Facility. A barrier wall is installed on the south end of X-749 Landfill and where the existing east X-749 trench is located, effectively containing contamination within this landfill. In areas of the plume where TCE concentrations are predicted to fall below 5 Fg/L, wells are turned off at 5, 10, and 15 years to facilitate movement of the contaminated groundwater to the wells still in operation. The existing X-120 horizontal well, the Peter Kiewit trench and the southwest X-749 trench continue operation. Implementation of phytoremediation begins in the 21^{st} year. With implementation of phytoremediation, all active remedial measures, except the southwest X-749 Landfill and the Peter Kiewit trenches, are removed from operation. Monitoring and deed restrictions are also implemented in this alternative.

C Alternative 5 - Phytoremediation

Approximately 27.5 acres of hybrid poplars are planted in this alternative. A barrier wall is installed on the south end of X-749 Landfill and where the existing east X-749 trench is located, effectively containing contamination within this landfill. The southwest X-749 and Peter Kiewit trenches continue operation. Monitoring and deed restrictions are also implemented in this alternative.

• Alternative 6 - Enhanced Bioremediation and Phytoremediation

This alternative includes bioremediation and phytoremediation, operation of selected existing trenches, and installation of containment walls. Enhanced bioremediation is considered in an area of 5.9 acres coinciding with the current Gallia TCE distribution exceeding 100 Fg/L near the X-120 horizontal well. Enhanced bioremediation and phytoremediation are considered in an area of 8.3 acres covering the current Gallia TCE distribution exceeding 1,000 Fg/L west of the X-749 Landfill. Phytoremediation is considered in two areas (11.9 acres and 1.7 acres) that are located south and east of the X-749 Landfill, respectively. Enhanced bioremediation is performed from 0 to 2 years. Phytoremediation is considered effective beginning the 3^{rd} year. The X-120 horizontal well is operated from 0 to 2 years. A barrier wall is installed on the south end of the X-749 Landfill and where the existing east X-749 trench is located. Monitoring and deed restrictions are also implemented in this alternative.

The remainder of this section presents a detailed description of the alternatives. This discussion develops the approach for implementing each alternative. The parameters discussed within each detailed alternative description are listed in Section 5.2. The following analyses are conducted for each alternative:

- technical,
- human health,

- environmental,
- institutional, and
- cost.

8.5.1 Alternative 1 - No Action

The no action alternative is retained throughout alternative analysis and evaluation for comparison with other alternatives involving active remedial measures. Under implementation of the no action alternative, no treatment, containment, removal, or monitoring of the environmental media at the X-749/X-120 Area would be performed. Unrestricted access to PORTS in its current condition would be allowed, and no present or future restrictions on access or land use would be implemented. No time frame is associated with implementation of this alternative.

8.5.1.1 Technical analysis

Performance. No performance is associated with Alternative 1 because it involves no action. Under the no action alternative, the contaminant toxicity, mobility, and total volume may be reduced through natural processes of attenuation (i.e., sorption). This alternative is included as a baseline for comparison with the other alternatives.

For the no action alternative, solute transport was simulated for a 30-year time period. Over the duration of the simulation, the X-749/X-120 Area plume, as represented by the model, migrates southward to the DOE property boundary and eastward toward Big Run Creek (Figures 8.5, 8.6, and 8.7). If no action is taken, the area of the contaminant plume exceeding the MCL is predicted to encompass over 5,719,000 ft^2 with the highest contaminant concentration predicted to be 2,788 µg/L at the end of 30 years.

Reliability. Evaluation of reliability is not applicable for this alternative because no active remediation measures are proposed. Monitoring to verify the model predictions is also not part of this alternative. Alternative 1 is included only for comparative purposes to support the evaluation of the active remedial measures.

Implementability. Alternative 1 could be easily implemented immediately upon authorization. This alternative assumes that DOE would no longer maintain control of the property and current security and access restrictions would be discontinued. No monitoring effort is included in this alternative.

Figure 8.5

Figure 8.6

Figure 8.7

Safety. Under Alternative 1, remediation activities would not be conducted that would present safety hazards to onsite workers or the local community; however, discontinuation of existing site access restrictions could increase safety risks (i.e., accidental injury) because trespassers would have access to the site.

8.5.1.2 Human health analysis

Short-Term Exposure Risks. No short-term exposure risks other than the continued exposure risk to onsite workers would be associated with this alternative. No current exposures to groundwater exist.

Long-Term Exposure Risks. The long-term exposure risk associated with Alternative 1 would be unacceptable because the alternative would not meet the stated RAOs. Because Alternative 1 provides neither institutional controls nor long-term protection of human health, no permanence is associated with Alternative 1. The no action alternative is provided only to serve as a basis to compare the effectiveness of other proposed alternatives.

8.5.1.3 Environmental analysis

Construction would not be necessary for Alternative 1; therefore, this alternative would pose no short-term risks to ecological receptors in the area and would have no adverse effects on wetlands, archeological, and cultural resources, or critical habitats for threatened and endangered species. No socioeconomic effects to the local community are anticipated from implementation of this alternative. The X-749/X-120 Area is not in a 100- or 500-year flood plain; therefore, neither adverse nor beneficial influences on flood elevations would occur as a result of no action.

8.5.1.4 Institutional analysis

Appendix B provides a preliminary list of federal and state ARARs and other guidance that may be considered for the groundwater in the X-749/X-120 Area. Alternative 1 will not achieve all RAOs and will not meet ARARs.

8.5.1.5 Cost analysis

No costs are associated with Alternative 1.

8.5.2 Alternative 2 - No Further Action

Institutional controls for Alternative 2 include deed and access restrictions and groundwater monitoring. Deed restrictions would prevent residential development in the X-749/X-120 Area.

Groundwater monitoring would be initiated to aid in the assessment of contaminated groundwater migration beyond current plume boundaries. The groundwater monitoring program would use existing monitoring wells to monitor contaminant fate and transport.

8.5.2.1 Technical analysis

Alternative-specific assumptions.

(1) Institutional controls are effective in preventing access to the site or to contaminants.

(2) The existing X-120 horizontal well, X-749 trenches, and Peter Kiewit trench will continue to operate.

Performance. Under this alternative, contaminant mobility and total volume would be reduced through natural attenuation (e.g., sorption) and groundwater capture and treatment. (See Figures 8.8, 8.9, and 8.10). If No Further Action is taken, the area of the contaminant plume exceeding the MCL is predicted to encompass over 4,058,000 ft^2 with the highest contaminant concentration predicted to be 1,343 µg/L at the end of 30 years.

Deed and land use restrictions, in combination with groundwater capture and treatment, would reduce the likelihood of exposure of current and future onsite workers and the general public to contaminated groundwater. The useful life of this alternative could be indefinite; however, its continuation would depend on the ability to operate and maintain existing remedial measures and to maintain and enforce deed and land use restrictions until risk is reduced to acceptable levels through natural attenuation.

Figure 8.8

Figure 8.9

Figure 8.10

Reliability. Deed and land use restrictions would limit future land use and prohibit development of contaminated groundwater for potable water supply. Groundwater monitoring would be used to determine if contaminated groundwater is migrating to surface-water bodies.

The groundwater monitoring wells would be inspected and sampled by trained personnel. Maintenance of monitoring point wellheads and the groundwater treatment facilities would be relatively straightforward and could be successfully performed by PORTS maintenance personnel. Labor and materials required to maintain the equipment described above are expected to be readily available for at least 30 years.

Implementability. Deed and land use restrictions can be easily implemented. The existing monitoring system is adequate for this alternative.

Safety. The safety hazards associated with Alternative 2 are related to site-specific monitoring activities. Safety hazards to workers would include those commonly associated with monitoring activities. Potential hazards to workers at the site should be mitigated through compliance with OSHA regulations and a site-specific health and safety plan. Activities conducted under this alternative would be coordinated with adjacent facility operations to assure that potential worker hazards from other operations are minimized. No potential safety hazards exist for the community or the environment.

8.5.2.2 Human health analysis

Short-Term Exposure Risks. The short-term exposure risk associated with implementation of Alternative 2 would involve potential increased exposure of onsite personnel to contaminants during monitoring and maintenance activities. Potential exposure could be controlled and minimized with implementation of a site-specific health and safety plan. In addition, regulatory mandates and ALARA principles would be observed to limit and prevent exposure of workers to contaminants. Implementation of this alternative would pose no short-term risks to neighboring populations because the contaminated material would remain onsite.

Long-Term Exposure Risks. The long-term exposure risk associated with Alternative 2 would be acceptable because institutional controls, including industrial requirements for workers and implementing deed and land use restrictions to prevent development of contaminated groundwater, are expected to satisfy the RAOs for future onsite workers. RAOs related to long-term risk to ecological receptors will not be met because contaminated groundwater is predicted to migrate to surface water.

8.5.2.3 Environmental analysis

Since no construction activities are associated with this alternative, risks to ecological receptors in the area would be minimal and no adverse effects on wetlands, archeological and cultural resources, or critical habitats for threatened and endangered species would be expected. Neither adverse nor beneficial influences on flood elevations would result because the X-749/X-120 Area is not in a 100- or 500-year flood plain. No socioeconomic effects on the local community are anticipated from implementation of this alternative.

8.5.2.4 Institutional analysis

Appendix B provides a preliminary list of federal and state ARARs and other guidance that will potentially be considered for the remediation of the X-749/X-120 Area groundwater through institutional controls and natural attenuation. Alternative 2 does not meet preliminary ARARs and TBC guidance identified in Appendix B.

8.5.2.5 Cost analysis

The estimated costs associated with Alternative 2 are provided in Table 8.4. The general assumptions used to develop the cost analysis are provided in Appendix D.

Table 8.4. Summary of Costs for X-749/X-120 Area Alternative 2, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative 2 No Further Action	Capital Cost ($ thousands)				O&M Cost ($ thousands)	
	Direct[a]	Indirect[a]	Total[a]	Present Worth[b]	Annual[a]	Present Worth[b]
Base Actions	$0	$0	$0	$0		
Monitoring, Maintenance, Operations	NA	NA	NA	NA	$371	
Base Actions Totals	**$0**	**$0**	**$0**	**$0**		**$5,974**

[a]Costs are escalated per DOE guidance.
[b]Present worth costs for 30-year study calculated by the Building Life-Cycle Cost (BLCC) analysis (version 4.20-95).
[c]The total, unescalated O&M cost is divided by the number of years duration and then escalated to the first year of implementation.

8.5.3 Alternative 3 - Pump and Treat

This alternative includes 34 extraction wells with treatment of contaminated groundwater at an expanded X-625 Groundwater Treatment Facility. The existing X-120 horizontal well, the Peter Kiewit trench and the southwest X-749 trench continue operation. A barrier wall is installed at the south end of the X-749 Landfill and where the existing east X-749 trench is located, effectively containing contamination within this landfill. Monitoring and deed restrictions are also implemented in this alternative.

Pump and treat is a proven groundwater remediation strategy. Extraction well systems are designed to use the minimal number of wells to capture and remove contaminated groundwater. The X-625 Groundwater Treatment Facility will be expanded to process the additional flow from the proposed extraction system. In areas of the plume where TCE concentrations are predicted to fall below 5 Fg/L, wells are turned off at the end of every 5-year interval to facilitate movement of the contaminated groundwater to the wells still in operation. Table 8.5 shows the periods of operation and extraction rates for the wells used in this alternative.

8.5.3.1 Technical analysis

Alternative-specific assumptions.

(1) A 34 well groundwater extraction network will be installed.

(2) The existing X-625 Groundwater Treatment Facility will be expanded to treat the volume of water extracted by the new extraction well network.

(3) Barrier walls will be installed on the east and south sides of the X-749 Landfill. The southwest X-749 trench will continue to capture contaminated groundwater from the landfill for subsequent treatment at the X-622 Groundwater Treatment Facility. These actions will effectively contain contaminants within the boundary of the X-749 Landfill.

(4) The existing X-120 horizontal extraction well and the Peter Kiewit Collection Trench will remain in operation.

Table 8.5. X-749/X-120 Area Alternative 3 Extraction Well Rates and Periods of Operation

Well ID	GPM (0-5 yrs)	GPM (6-10 yrs)	GPM (11-15 yrs)	GPM (16-20 yrs)	GPM (21-25 yrs)	GPM (26-30 yrs)
EW1	0.5	0.5	0.5			
EW2	0.5	0.5	0.5	0.5	0.5	0.5
EW3	0.5	0.5	0.5	0.5	0.5	0.5
EW4	0.5	0.5	0.5	0.5	0.5	0.5
EW5	1	1	1	1	1	
EW6	1	1	1	1		
EW7	1	1	1	1		

Well ID	GPM (0-5 yrs)	GPM (6-10 yrs)	GPM (11-15 yrs)	GPM (16-20 yrs)	GPM (21-25 yrs)	GPM (26-30 yrs)
EW8	0.5	0.5	0.5	0.5		
EW9	0.5					
EW10	0.5					
EW11	1.5	1.5	1.5			
EW12	1	1				
EW13	1.5	1.5				
EW14	1.5	1.5	1.5	1.5	1.5	
EW15	1	1				
EW16	1	1	1	1		
EW17	1					
EW18	1.5	1.5	1.5	1.5	1.5	1.5
EW19	1	1	1	1	1	
EW20	2	2	2	2	2	2
EW21	0.5	0.5	0.5	0.5		
EW22	0.5					
EW23	0.5					
EW24	0.5	0.5	0.5			
EW25	0.5	0.5	0.5	0.5		
EW26	0.5	0.5				
EW27	0.5					
EW28	0.5	0.5	0.5			
EW41	0.5	0.5	0.5			
EW42	0.5	0.5	0.5			
X749-75G	0.5					
X749-80G	0.5	0.5				
X749-78G	0.5	0.5				
X749-79G	0.5	0.5	0.5			

Performance. Alternative 3 would be effective at achieving the RAO for onsite personnel by using institutional controls to prevent exposure to contaminated groundwater. Deed restrictions would prevent development of contaminated groundwater in the X-749/X-120 Area. Access and land use restrictions would limit exposure to contaminated groundwater by requiring excavation permits and stipulations on the maximum depth of excavations permissible in the area. The groundwater monitoring program would use existing monitoring wells to assess contaminant fate and transport.

The groundwater flow and transport model discussed in Appendix E was used to predict the pumping rates of the extraction wells and their effectiveness in mitigating the existing groundwater plume. Figures 8.11 shows the initial plume configuration and the location of proposed extraction wells. It was necessary to install ten extraction wells in the eastern extension of the VOC plume near the Peter Kiewit Landfill in order to meet the remedial action objectives. Figures 8.12, 8.13, 8.14, 8.15, 8.16, and 8.17 illustrate the Gallia TCE plume concentrations at the end of each 5-year interval. The highest concentration of TCE remaining after 30 years would be approximately 43 Fg/L. The estimated remaining areal extent of the TCE plume exceeding the MCL is 250,000 ft^2.

This alternative achieves a risk level of 1×10^{-4} in less than 15 years. Continued operation of this alternative will achieve an approximate risk level of 8.2×10^{-6} in 30 years.

Reliability. The use of groundwater extraction wells has been widely demonstrated as a reliable and effective method of groundwater remediation. The extraction wells will remove groundwater with COC concentrations exceeding site-specific PRGs and the treatment system will be used to remove the contaminants. Components used (pumps, etc.) are considered reliable; however, as with any mechanical system, active maintenance is required. Deed and land use restrictions would limit future land use, place limitations on the depth of excavations, and prohibit development of groundwater for potable water supplies.

Implementability. Future reindustrialization projects may impact the implementation of Alternative 3. However, OEPA and U.S. DOE will work with prospective vendors to insure that equitable solutions are achieved. These impacts are discussed further in Section 8.6.1.3. If possible future reindustrialization projects are not considered, then the time required to fully implement this alternative would be 12-18 months. Standard construction equipment and materials are readily available for installing the extraction wells. Fugitive dust emissions must be considered for all construction activities, and air monitoring would be part of any such activities. Adequate access is available to all affected areas. Deed and land use restrictions can be easily implemented. The existing monitoring system is adequate for this alternative.

Figure 8.11

Figure 8.12

Figure 8.13

Figure 8.14

Figure 8.15

Figure 8.16

Figure 8.17

Safety. Safety hazards would be encountered during maintenance and construction activities, although these hazards are not expected to be any greater than those experienced in private industry for operation of similar equipment. Potential hazards to workers at the site would be mitigated through compliance with OSHA regulations and a site-specific health and safety plan. If construction activities become necessary (e.g., replacement of a monitoring or extraction well), a detailed study of the site would identify the types of utilities and locations that could be affected by construction. Utilities that pose a hazard to workers would be deactivated before construction. Such activities would be coordinated with adjacent facility operations to assure that potential worker hazards from other operations are minimized. Implementation of this alternative would pose no safety hazards for neighboring populations because contaminants would remain onsite.

8.5.3.2 Human health analysis

Short-Term Exposure Risks. Although risks exist due to maintenance and construction activities required for Alternative 3, they are mitigated by implementation of and adherence to health and safety plans and ALARA principles. Risks from O&M activities should be no greater than those incurred in
private industry for comparable types of labor. Implementing this alternative would pose no short-term risk to neighboring populations because activities would be performed onsite.

Long-Term Exposure Risks. Long-term exposure risks fall within the acceptable range of risk because extraction wells will remove a significant mass of TCE, as well as reduce the size of the existing groundwater contaminant plume. No ecological receptors will be impacted because groundwater contamination will not migrate to surface water bodies. Development of the Gallia water-bearing unit as a drinking water source is prevented by both the low groundwater yield and by implementation of institutional controls.

8.5.3.3 Environmental analysis

Construction would be necessary for Alternative 3, but risks to ecological receptors in the area would be minimal and no adverse effects on wetlands, archeological and cultural resources, or critical habitats for threatened or endangered species would be expected. Neither adverse nor beneficial influences on flood elevations would result because the X-749/X-120 Area is not located in a 100- or 500-year flood plain.

No socioeconomic effects on the local community are anticipated from implementation of this alternative.

8.5.3.4 Institutional analysis

Appendix B provides a preliminary list of federal and state ARARs and other guidance that will potentially be considered for the remediation of groundwater through institutional controls and source reduction. This alternative will reduce contaminant concentrations to below PRGs where practicable and meet all RAOs.

8.5.3.5 Cost analysis

The estimated costs associated with Alternative 3 are provided in Table 8.6. The general assumptions used to develop the cost analysis are provided in Appendix D of this report.

Table 8.6. Summary of Costs for X-749/X-120 Area Alternative 3, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative 3 Pump and Treat	**Capital Cost ($ thousands)**				**O&M Cost ($ thousands)**	
	Direct[a]	**Indirect[a]**	**Total[a]**	**Present Worth[b]**	**Annual[a]**	**Present Worth[b]**
Base Actions						
General Requirements,	$ 279					
Site Work	$ 30					
Construction	$ 2,252					
Waste	$ 43					
Subtotal:	$ 2,604	$333	$2,937			
Monitoring, Maintenance, Operations	NA	NA	NA		$759	
Base Actions Totals	**$2,604**	**$333**	**$2,937**	**$2,564**		**$12,749**

[a]Costs are escalated per DOE guidance.
[b]Present worth costs for 30-year study calculated by the Building Life-Cycle Cost (BLCC) analysis (version 4.20-95).
[c]The total, unescalated O&M cost is divided by the number of years duration and then escalated to the first year of implementation.

8.5.4 Alternative 4 - Pump and Treat with Subsequent Phytoremediation

This alternative includes 34 extraction wells operated for 20 years with treatment of extracted groundwater at the expanded X-625 and X-622 Groundwater Treatment Facilities. In areas of the plume where TCE concentrations are predicted to fall below 5 Fg/L, wells are turned off at 5, 10, and 15 years to facilitate movement of the contaminated groundwater to the wells still in operation. The existing X-120 horizontal well, the Peter Kiewit trench and the southwest X-749 trench continue operation through the first 20 years of this scenario. Implementation of phytoremediation begins in the 21st year with the planting of hybrid poplar trees over significant portions of the X-749/X-120 Area groundwater plume. Table 8.7 summarizes the phytoremediation parameters for each zone.

With implementation of phytoremediation, all active remedial measures except the southwest X-749 Landfill and the Peter Kiewit trenches, cease operation. Barrier walls are installed on the south end of X-749 Landfill and where the existing X-749 east trench is located, effectively containing contamination within this landfill. Monitoring and deed restrictions are also implemented in this alternative.

Table 8.7. X-749/X-120 Area Alternative 4 - Phytoremediation Zone Parameters

Zone #	Area (Acres)	Area (ft²)	Trees/Acre	Total Trees	Rate/Tree (gpd)	Rate/Zone (gpd)
1	5.65	246,250	400	2,259	15	33,892
2	4.14	180,313	400	1,654	15	24,817
TOTALS	**9.8**	**426,563**		**3,913**		**58,709**

Pump and treat is a proven groundwater remediation strategy. Extraction well systems and the layout of the trees to be planted are designed to maximize efficiency to capture and remove contaminated groundwater. Table 8.8 shows the periods of operation and extraction rates for the wells used in this alternative.

Table 8.8. X-749/X-120 Area Alternative 4 Extraction Well Rates and Periods of Operation

Well ID	GPM (0-5 yrs)	GPM (6-10 yrs)	GPM (11-15 yrs)	GPM (16-20 yrs)
EW1	0.5	0.5	0.5	
EW2	0.5	0.5	0.5	0.5

Well ID	GPM (0-5 yrs)	GPM (6-10 yrs)	GPM (11-15 yrs)	GPM (16-20 yrs)
EW3	0.5	0.5	0.5	0.5
EW4	0.5	0.5	0.5	0.5
EW5	1	1	1	1
EW6	1	1	1	1
EW7	1	1	1	1
EW8	0.5	0.5	0.5	0.5
EW9	0.5			
EW10	0.5			
EW11	1.5	1.5	1.5	
EW12	1	1		
EW13	1.5	1.5		
EW14	1.5	1.5	1.5	1.5
EW15	1	1		
EW16	1	1	1	1
EW17	1			
EW18	1.5	1.5	1.5	1.5
EW19	1	1	1	1
EW20	2	2	2	2
EW21	0.5	0.5	0.5	0.5
EW22	0.5			
EW23	0.5			
EW24	0.5	0.5	0.5	
EW25	0.5	0.5	0.5	0.5
EW26	0.5	0.5		
EW27	0.5			
EW28	0.5	0.5	0.5	
EW41	0.5	0.5	0.5	
EW42	0.5	0.5	0.5	
X749-75G	0.5			
X749-80G	0.5	0.5		
X749-78G	0.5	0.5		
X-749-79G	0.5	0.5	0.5	

8.5.4.1 Technical analysis

Alternative-specific assumptions.

(1) A 34 well groundwater extraction network will be installed.

(2) The existing X-625 Groundwater Treatment Facility will be expanded to treat the volume of water extracted by the new extraction well network.

(3) Barrier walls will be installed on the east and south side of the X-749 Landfill. The southwest X-749 trench will continue to capture contaminated groundwater from the landfill for subsequent treatment at the X-622 Groundwater Treatment Facility. These actions will effectively contain contaminants within the boundary of the X-749 Landfill.

(4) The existing X-120 horizontal extraction well and the Peter Kiewit Collection Trench will remain in operation.

(5) All wells will be turned off with the implementation of phytoremediation measures in the 21st year of the project.

Performance. Alternative 4 would be effective at achieving the RAO for onsite personnel by using institutional controls to prevent exposure to contaminated groundwater. Deed restrictions would prevent development of contaminated groundwater in the X-749/X-120 Area. Access and land use restrictions would limit exposure to contaminated groundwater by requiring excavation permits and stipulations on the maximum depth of excavations permissible in the area. The groundwater monitoring program would use existing monitoring wells to assess contaminant fate and transport.

The groundwater flow and transport model discussed in Appendix E was used to predict the effectiveness of the extraction wells and trees in mitigating the existing groundwater plume. Figures 8.18, 8.19, 8.20, 8.21, 8.22, and 8.23 illustrate the predicted extent of the TCE plume at the end of each 5-year interval. The highest concentration of TCE remaining after 30 years is approximately 16Fg/L. The estimated remaining areal extent of the TCE plume exceeding the MCL at the end of 30 years is 638,000 ft^2.

This alternative achieves a risk level of 1×10^{-4} in less than 20 years. Continued operation of this alternative will achieve an approximate risk level of 3.08×10^{-6} in 30 years.

Figure 8.18

Figure 8.19

Figure 8.20

Figure 8.21

Figure 8.22

Figure 8.23

Reliability. The use of groundwater extraction wells and phytoremediation have been demonstrated to be viable methods of groundwater remediation (Schnoor et al. 1995). The extraction wells will initially remove a significant portion of the most highly contaminated groundwater. Hybrid poplar trees will be planted at the appropriate time to ensure they are mature enough to be effective when the extraction wells cease operation. Deed and land use restrictions would limit future land use, place limitations on the depth of excavations, and prohibit development of groundwater for potable water supplies.

Implementability. Future reindustrialization projects may impact the implementation of Alternative 4. These impacts are discussed in Section 8.6.1.3. If possible future reindustrialization projects are not considered, then installation of groundwater extraction wells, and hybrid poplar trees in the X-749/X-120 plume area, and barriers at the X-749 Landfill for Alternative 4 could be implemented in 12-18 months except for the initial two years needed for the trees to mature. Standard drilling and construction equipment will be used and is readily available. Because the current owner will occupy the site for the indefinite future, no additional deed and land use restrictions are currently necessary. Additional restrictions can be put in place if the status of the site changes in the future. Fugitive dust emissions must be considered for all construction activities, and air monitoring would be part of any such activities. Adequate roadways are available to all affected areas; however, the increase in vehicular traffic resulting from remediation efforts should be assessed for possible effects on enrichment operations.

Safety. Safety hazards would be encountered during maintenance and construction activities, although these hazards are not expected to be any greater than those experienced in private industry for operation of similar equipment. Potential hazards to workers at the site would be mitigated through compliance with OSHA regulations and a site-specific health and safety plan. If construction activities become necessary (e.g., replacement of a monitoring or extraction well), a detailed study of the site would identify the types of utilities and locations that could be affected by construction. Utilities that pose a hazard to workers would be deactivated before construction. Such activities would be coordinated with adjacent facility operations to assure that potential worker hazards from other operations are minimized. Implementation of this alternative would pose no safety hazards for neighboring populations because contaminants would remain onsite.

8.5.4.2 Human health analysis

Short-Term Exposure Risks. The short-term exposure risks associated with implementation of

Alternative 4 would involve the potential for increased exposure of onsite workers (remediation workers) to contaminants, when compared with other alternatives, because these alternatives are more treatment intensive. Because maintenance and construction are required, the threat of exposure is greater, but risks will be minimized with implementation of and adherence to health and safety plans and ALARA principles. Risks from O&M activities should be no greater than risks incurred in private industry for comparable types of labor. Implementing this alternative would pose no short-term risk to neighboring populations because activities would be performed onsite.

Long-Term Exposure Risks. Long-term exposure risks fall within the acceptable range of risk because extraction wells and the hybrid poplars will remove a significant mass of TCE, as well as reduce the size of the existing groundwater contaminant plume. No ecological receptors will be impacted because groundwater contamination will not migrate to surface water bodies. Development of the Gallia water-bearing unit as a drinking water source is prevented by both the low groundwater yield and by implementation of institutional controls.

8.5.4.3 Environmental analysis

Alternative 4 does not adversely affect ecological receptors in the X-749/X-120 Area. Future risks would be equal to current risks or reduced as contaminants are removed during remediation.

Implementation of this alternative would have no adverse effects on wetlands, archeological resources, cultural resources, or critical habitats for threatened or endangered species. Neither adverse nor beneficial influences on flood elevations would result because the X-749/X-120 Area is not located in a 100- or 500-year floodplain. No socioeconomic effects on the community are anticipated from implementation of this alternative.

8.5.4.4 Institutional analysis

Appendix B provides a preliminary list of federal and state ARARs and other guidance that will potentially be considered for the remediation of groundwater through institutional controls and in situ treatment. This alternative will reduce contaminant concentrations to below PRGs where practicable and meet RAOs.

8.5.4.5 Cost analysis

The estimated costs associated with Alternative 4 are provided in Table 8.9. The general assumptions used to develop the cost analysis are provided in Appendix D of this report.

Table 8.9. Summary of Costs for X-749/X-120 Area Alternative 4, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative 4 Pump and Treat with Subsequent Phytoremediation	Capital Cost ($ thousands)				O&M Cost ($ thousands)	
	Direct[a]	Indirect[a]	Total[a]	Present Worth[b]	Annual[a]	Present Worth[b]
Base Actions						
General Requirements	$ 279					
Site Work	$ 30					
Construction	$ 2,252					
Waste	$ 43					
Subtotal:	$ 2,604	$333	$2,937			
Monitoring, Maintenance, Operations	NA	NA	NA		$693	
Base Actions Totals	**$ 2,604**	**$333**	**$2,937**	**$2,564**		**$11,623**

[a]Costs are escalated per DOE guidance.
[b]Present worth costs for 30-year study calculated by the Building Life-Cycle Cost (BLCC) analysis (version 4.20-95).
[c]The total, unescalated O&M cost is divided by the number of years duration and then escalated to the first year of implementation.

8.5.5 Alternative 5 - Phytoremediation

This alternative consists of planting hybrid poplar trees in a significant portion of the X-749/X-120 Area plume. The Peter Kiewit trench and the southwest X-749 trench continue operation, but use of the X-120 horizontal well is discontinued. A barrier wall is installed on the south end of X-749 Landfill and where the existing east X-749 trench is located, effectively containing contamination within this landfill. Monitoring and deed restrictions are also implemented in this alternative.

Phytoremediation is a proven groundwater remediation technology and is currently being evaluated at the site. Approximately 27.5 acres of hybrid poplar trees are planted in this alternative to reduce the size and toxicity of the contaminant plume. The depth to groundwater in the zones chosen for phytoremediation is less than 15 ft and the depth to the bottom of the Minford formation over much of this area is 15 ft or less. Trees will readily root at these depths. In areas where the depth to the bottom of the Minford exceeds 15 ft, the trees will still be effective at removing groundwater, however a smaller percentage will be from the

Gallia. Following implementation, performance can be evaluated to assess if the trees are extracting sufficient groundwater from the Gallia. Table 8.10 summarizes the phytoremediation parameters for each zone shown on Figures 8.24, 8.25, and 8.26.

Table 8.10. X-749/X-120 Area Alternative 5 - Phytoremediation Zone Parameters

Zone #	Area (acres)	Area (ft^2)	Trees/acre	Total Trees	Rate/Tree (gpd)	Rate/Zone (gpd)
1	4.2	182,952	40	168	15	2,518
2	3.3	143,748	40	132	15	1,978
3	8.1	352,836	40	324	15	4,856
4	3.5	152,460	40	140	15	2,098
5	1.5	65,340	120	180	15	2,698
6	5.7	248,292	200	1,140	15	17,086
7	1.2	52,272	200	240	15	3,597
TOTALS	**27.5**	**1,197,900**		**2,324**		**34,831**

Once an acceptable level of risk is achieved, any remaining trees will continue to provide containment of the plume and further reduce contaminant levels.

Figure 8.24

Figure 8.25

Figure 8.26

8.5.5.1 Technical analysis

Alternative-specific assumptions.

(1) Approximately 27.5 acres of hybrid poplar trees will reduce the size and toxicity of the contaminant plume.

(2) Barrier walls will be installed on the east and south side of the X-749 Landfill. The southwest X-749 trench will continue to capture contaminated groundwater from the landfill for subsequent treatment at the X-622 Groundwater Treatment Facility. These actions will effectively contain contaminants within the boundary of the X-749 Landfill.

(3) Operation of the X-749 southwest trench and the Peter Kiewit Collection Trench continue.

Performance. Alternative 5 would be effective in achieving the RAO for onsite personnel by using institutional controls to prevent exposure to contaminated groundwater. Deed restrictions would prevent development of contaminated groundwater in the X-749/X-120 Area. Access and land use restrictions would limit exposure to contaminated groundwater by requiring excavation permits and stipulations on the maximum depth of excavations permissible in the area. Contaminants will be contained within the capture zone of the hybrid poplar trees. Groundwater monitoring would be initiated to determine if contaminated groundwater migrates beyond the X-749/X-120 Area. The groundwater monitoring program would use existing monitoring wells to assess contaminant fate and transport.

The groundwater flow and transport model discussed in Appendix E was used to predict the effectiveness of phytoremediation in mitigating the existing groundwater plume. Figures 8.24, 8.25, and 8.26 illustrate the predicted extent of the TCE plume at the end of each 10-year interval. This technology would effectively reduce the areal extent and contaminant concentrations within the X-749/X-120 Area plume. The highest concentration of TCE remaining after 30 years would be 48 Fg/L. The estimated areal extent of the TCE plume exceeding the MCL at the end of 30 years is 273,000 ft^2.

This alternative achieves a risk level of 1×10^{-4} in less than 20 years. Continued operation of this alternative will achieve an approximate risk level of 9.2×10^{-6} in 30 years.

Reliability. The use of hybrid poplar trees is a reliable method for removing COCs from groundwater. Deed and land use restrictions would limit future land use, place limitations on the depth of excavations, and prohibit development of groundwater for potable water supplies.

Maintenance of the hybrid poplar trees, monitoring point wellheads and the groundwater treatment facilities would be relatively straightforward and could be successfully performed by PORTS maintenance personnel. Labor and materials required to maintain the equipment described above are expected to be readily available for at least 30 years.

Implementability. Future reindustrialization projects may impact the implementation of Alternative 5. These impacts are discussed in Section 8.6.1.3. If possible future reindustrialization projects are not considered, then installation of hybrid poplar trees in the X-749/X-120 plume area and barriers at the X-749 Landfill for Alternative 5 could be implemented in 12-18 months. Standard construction equipment will be used. Materials needed for construction are readily available and limited training will be required. Because the current owner will occupy the site for the indefinite future, no additional deed and land use restrictions are currently necessary. Additional restrictions can be put in place if the status of the site changes in the future. Fugitive dust emissions must be considered for all construction activities, and air monitoring would be part of any such activities. Adequate roadways are available to all affected areas; however, the increase in vehicular traffic resulting from remediation efforts should be assessed for possible effects on enrichment operations.

Safety. Safety hazards would be encountered during maintenance and construction activities, although these hazards are not expected to be any greater than those experienced in private industry for operation of similar equipment. Potential hazards to workers at the site would be mitigated through compliance with OSHA regulations and a site-specific health and safety plan. If construction activities become necessary (e.g., replacement of a monitoring well), a detailed study of the site would identify the types of utilities and locations that could be affected by construction. Utilities that pose a hazard to workers would be deactivated before construction. Such activities would be coordinated with adjacent facility operations to assure that potential worker hazards from other operations are minimized. Implementation of this alternative would pose no safety hazards for neighboring populations because contaminants would remain onsite.

8.5.5.2 Human health analysis

Short-Term Exposure Risks. The short-term exposure risk associated with implementation of Alternative 5 would involve a potential increased exposure of onsite personnel and remediation workers to contaminants. The workers could be exposed to contaminants during tree planting activities, construction activities, and monitoring. Onsite personnel also could be exposed to contaminants through fugitive dust emissions. Potential exposure could be controlled and minimized with implementation of a site-specific health and safety plan. In addition, regulatory mandates and ALARA principles would be observed to limit and prevent exposure of remediation workers to contaminants. Implementation of this alternative would pose no short-term risks to neighboring populations because the contaminated material would remain onsite.

Long-Term Exposure Risks. The long-term exposure risk associated with Alternative 5 would be acceptable because the hybrid poplar trees are expected to satisfy the RAOs for future onsite workers by removing and treating contaminants detected in the groundwater and implementing deed and land use restrictions to prevent development of contaminated groundwater.

8.5.5.3 Environmental analysis

Alternative 5 does not adversely affect ecological receptors in the X-749/X-120 Area. Future risks would be equal to current risks or reduced as contaminants are removed during remediation.

Implementation of this alternative would have no adverse effects on wetlands, archeological resources, cultural resources, or critical habitats for threatened or endangered species. Neither adverse nor beneficial influences on flood elevations would result because the X-749/X-120 Area is not located in a 100- or 500-year floodplain. No socioeconomic effects on the community are anticipated from implementation of this alternative.

8.5.5.4 Institutional analysis

Appendix B provides a preliminary list of federal and state ARARs and other guidance that will potentially be considered for the remediation of groundwater through institutional controls and phytoremediation. This alternative will reduce contaminant concentration to below PRGs where practicable and meet RAOs.

8.5.5.5 Cost analysis

The estimated costs associated with Alternative 5 are provided in Table 8.11. The general assumptions used to develop the cost analysis are provided in Appendix D of this report.

Table 8.11. Summary of Costs for X-749/X-120 Area Alternative 5, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative 5 Phytoremediation	**Capital Cost ($ thousands)**				**O&M Cost ($ thousands)**	
	Direct[a]	**Indirect[a]**	**Total[a]**	**Present Worth[b]**	**Annual[a]**	**Present Worth[b]**
Base Actions						
Construction	$ 584					
Subtotal:	$ 584	$105	$689			
Monitoring, Maintenance, Operations	NA	NA	NA		$334	
Base Actions Totals	**$ 584**	**$105**	**$689**	**$602**		**$5,433**

[a]Costs are escalated per DOE guidance.
[b]Present worth costs for 30-year study calculated by the Building Life-Cycle Cost (BLCC) analysis (version 4.20-95).
[c]The total, unescalated O&M cost is divided by the number of years duration and then escalated to the first year of implementation.

8.5.6 Alternative 6 - Enhanced Bioremediation and Phytoremediation

This alternative consists of a combination of injection of a compound to enhance bioremediation and planting hybrid poplar trees in selected portions of the X-749/X-120 Area plume. The Peter Kiewit trench and the southwest X-749 trench continue operation, but the X-120 horizontal well is operated for a 2 year period then discontinued. A barrier wall is installed on the south end of the X-749 Area and where the existing east X-749 trench is located, effectively containing contamination within this landfill. Monitoring and deed restrictions are also implemented in this alternative.

Phytoremediation is a proven groundwater remediation technology. Approximately 22 acres of hybrid poplar trees are planted in this alternative to reduce the size and toxicity of the contaminant plume. Table 8.12 summarizes the phytoremediation parameters for each zone shown on Figures 8.27, 8.28, and 8.29.

Figure 8.27

Figure 8.28

Figure 8.29

Enhanced bioremediation is a proven groundwater remedial technology that is currently being evaluated at this site. The data collected from this evaluation will determine if this technology is applicable in this area or other groundwater contaminant areas at this site. For comparison to other alternatives discussed in this section of the text, it was assumed that no biodegradation beyond two years will occur. Approximately 14 acres are remediated by either injecting a nutrient solution at a regular spacing or in trenches associated with phytoremediation as at the X-740 Area. Information pertaining to a potential enhanced bioremediation technique is provided in Appendix F.

Table 8.12. X-749/X-120 Area Alternative 6 - Enhanced Bioremediation and Phytoremediation Zone Parameters

Zone #	Area (acres)	Area (ft^2)	Trees/acre	Total Trees	Rate/Tree (gpd)	Rate/Zone (gpd)
1	5.9	260,000	0	0		
2	8.3	360,000	100	650	8	5,000
3	11.9	520,000	100	1,400	15	21,000
4	1.7	74,000	100	340	15	5,000
TOTALS	**27.8**	**1,214,000**		**2,390**		**31,000**

Once an acceptable level of risk is achieved, any remaining trees will continue to provide containment of the plume and further reduce contaminant levels.

8.5.6.1 Technical analysis

Alternative-specific assumptions.

(1) Approximately 22 acres of hybrid poplar trees will reduce the size and toxicity of the contaminant plume.

(2) Approximately 14 acres of the X-749/X-120 Area will receive nutrients to enhance bioremediation.

(3) Barrier walls will be installed on the east and south side of the X-749 Landfill. The southwest X-749 trench will continue to capture contaminated groundwater from the landfill for subsequent treatment at the X-622 Groundwater Treatment Facility. These actions will effectively contain contaminants within the boundary of the X-749 Landfill.

(4) Operation of the X-749 southwest trench and the Peter Kiewit Collection Trench continue.

Performance. Alternative 6 would be effective in achieving the RAO for onsite personnel by using institutional controls to prevent exposure to contaminated groundwater. Deed restrictions would prevent development of contaminated groundwater in the X-749/X-120 Area. Access and land use restrictions would limit exposure to contaminated groundwater by requiring excavation permits and stipulations on the maximum depth of excavations permissible in the area. Contaminants will be contained within the capture zone of the hybrid poplar trees or captured by operating interceptor trenches. Groundwater monitoring would be initiated to determine if contaminated groundwater migrates beyond the X-749/X-120 Area. The groundwater monitoring program would use existing monitoring wells to assess contaminant fate and transport.

The groundwater flow and transport model discussed in Appendix E was used to predict the effectiveness of remediation in mitigating the existing groundwater plume. Figures 8.27, 8.28, and 8.29 illustrate the predicted extent of the TCE plume at the end of each 10-year interval. This technology would effectively reduce the areal extent and contaminant concentrations within the X-749/X-120 Area plume. The highest concentration of TCE remaining after 30 years would be approximately 90 Fg/L. The estimated areal extent of the TCE plume exceeding the MCL at the end of 30 years is 1,200,000 ft^2.

This alternative achieves a risk level of 1×10^{-4} in less than 20 years. Continued operation of this alternative will achieve an approximate risk level of 9.2×10^{-6} in 30 years.

Reliability. The use of hybrid poplar trees and enhanced bioremediation is a reliable method for removing COCs from groundwater. Deed and land use restrictions would limit future land use, place limitations on the depth of excavations, and prohibit development of groundwater for potable water supplies.

Maintenance of the enhanced bioremediation system will be limited and straightforward and be completed within 2 years. Maintenance of the hybrid poplar trees, monitoring point wellheads and the groundwater treatment facilities would be relatively straightforward and could be successfully performed by PORTS maintenance personnel. Labor and materials required to maintain the equipment described above are expected to be readily available for at least 30 years.

Implementability. This alternative was designed to accommodate possible reindustrialization projects. These impacts are discussed in Section 8.6.1.3. Installation of enhanced bioremediation and hybrid poplar trees in the X-749/X-120 plume area and barriers at the X-749 Landfill for Alternative 6 could be implemented in 12-18 months. Standard construction equipment will be used. Materials needed for construction are readily available and limited training will be required. Because the current owner will occupy the site for the indefinite future, no additional deed and land use restrictions are currently necessary. Additional restrictions can be put in place if the status of the site changes in the future. Fugitive dust emissions must be considered for all construction activities, and air monitoring would be part of any such activities. Adequate roadways are available to all affected areas; however, the increase in vehicular traffic resulting from remediation efforts should be assessed for possible effects on enrichment operations.

Safety. Safety hazards would be encountered during maintenance and construction activities, although these hazards are not expected to be any greater than those experienced in private industry for operation of similar equipment. Potential hazards to workers at the site would be mitigated through compliance with OSHA regulations and a site-specific health and safety plan. If construction activities become necessary (e.g., replacement of a monitoring well), a detailed study of the site would identify the types of utilities and locations that could be affected by construction. Utilities that pose a hazard to workers would be deactivated before construction. Such activities would be coordinated with adjacent facility operations to assure that potential worker hazards from other operations are minimized. Implementation of this alternative would pose no safety hazards for neighboring populations because contaminants would remain onsite.

8.5.6.2 Human health analysis

Short-Term Exposure Risks. The short-term exposure risk associated with implementation of Alternative 6 would involve a potential increased exposure of onsite personnel and remediation workers to contaminants. The workers could be exposed to contaminants during tree planting activities, construction activities, and monitoring. Onsite personnel also could be exposed to contaminants through fugitive dust emissions. Potential exposure could be controlled and minimized with implementation of a site-specific health and safety plan. In addition, regulatory mandates and ALARA principles would be observed to limit and prevent exposure of remediation workers to contaminants. Implementation of this alternative would pose no short-term risks to neighboring populations because the contaminated material would remain onsite.

Long-Term Exposure Risks. The long-term exposure risk associated with Alternative 6 would be acceptable because the hybrid poplar trees are expected to satisfy the RAOs for future onsite workers by removing and treating contaminants detected in the groundwater where practicable, and implementing deed and land use restrictions to prevent development of contaminated groundwater.

8.5.6.3 Environmental analysis

Alternative 6 does not adversely affect ecological receptors in the X-749/X-120 Area. Future risks would be equal to current risks or reduced as contaminants are removed during remediation.

Implementation of this alternative would have no adverse effects on wetlands, archeological resources, cultural resources, or critical habitats for threatened or endangered species. Neither adverse nor beneficial influences on flood elevations would result because the X-749/X-120 Area is not located in a 100- or 500-year floodplain. No socioeconomic effects on the community are anticipated from implementation of this alternative.

8.5.6.4 Institutional analysis

Appendix B provides a preliminary list of federal and state ARARs and other guidance that will potentially be considered for the remediation of groundwater through institutional controls and phytoremediation. Although this alternative will significantly reduce contamination and associated risks in the X-749/X-120 Area, PRGs established for the site will probably not be achieved.

8.5.6.5 Cost analysis

The estimated costs associated with Alternative 6 are provided in Table 8.13. The general assumptions used to develop the cost analysis are provided in Appendix D of this report.

Table 8.13. Summary of Costs for X-749/X-120 Area Alternative 6, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative 6 Enhanced and Phytoremediation	Capital Cost ($ thousands)				O&M Cost ($ thousands)	
	Direct[a]	Indirect[a]	Total[a]	Present Worth[b]	Annual[a]	Present Worth[b]
Base Actions						
General Requirements	$ 64					
Construction	5,093	437				
Subtotal:	$ 5,157	$ 437	$ 5,594			
Monitoring, Maintenance, Operations	NA	NA	NA		$ 496	
Base Actions Totals	**$ 5,157**	**$ 437**	**$ 5,594**	**$ 5,228**		**$ 10,182**

[a]Costs are escalated per DOE guidance.
[b]Present worth costs for 30-year study calculated by the Building Life-Cycle Cost (BLCC) analysis (version 4.20-95).
[c]The total, unescalated O&M cost is divided by the number of years duration and then escalated to the first year of implementation.

8.6 COMPARATIVE EVALUATION OF ALTERNATIVES

Direct comparative evaluation of alternatives identifies the advantages and disadvantages of selecting one alternative over another. The following comparative analyses are conducted:

- technical,
- human health,
- environmental,
- institutional, and
- cost

8.6.1 Technical Analysis

8.6.1.1 Performance

No performance is associated with Alternative 1 because no physical or administrative controls are implemented. Institutional controls would be implemented for Alternatives 2 through 6 and would be effective in reducing the likelihood of exposure of current and future onsite workers and the general public to contaminated groundwater. The continuing effectiveness of administrative controls would depend on

the ability to maintain and enforce deed and land use restrictions for the indefinite future. Alternatives 3 through 6 incorporate barrier walls on all sides of the X-749 Landfill except for the southwest groundwater collection trench, which remains in operation. Alternatives 3 through 6 would employ various combinations of extractive and in-situ technologies to reduce contaminant toxicity, mobility, and total volume. Plume size would be reduced, and contaminant concentrations would be reduced to below PRGs over significant portions of the X-749/X-120 Area. However, areas of groundwater contamination above PRGs would remain.

Model simulations of these alternatives indicate that it will be impossible to move a sufficient quantity of water through the Gallia saturated zone in the X-749/X-120 Area to effectively remediate groundwater and associated saturated soils within a 30-year time frame. Even with extensive application of best available technologies, the hydrogeologic conditions preclude achieving the target risk level of 1×10^{-6} within 30 years. However, these simulations do indicate that groundwater contaminant levels can be reduced to an acceptable risk level of 1×10^{-5} in a much shorter time frame, in effect attaining the concentrations which are as low as reasonably achievable given the constraints of the local hydrogeologic system. Table 8.14 summarizes the remaining TCE concentrations, areas of groundwater contamination, and the risk levels of the alternatives at various times during the model simulations.

Alternative 6 which includes enhanced bioremediation and phytoremediation combines two technologies to provide a high initial mass removal. Alternative 6 also reduces the area of aboveground operation and maintenance.

In one portion of the X-749 Area (Zone 2) enhanced bioremediation and phytoremediation are implemented together. Although no pilot testing of this combined technology has been performed, the two methods are expected to complement each other.

Regardless of the alternative implemented, an evaluation of system performance will be conducted during the 5th year of operation. If system performance is shown to be unsatisfactory, then recommendations for system improvement will be implemented.

8.6.1.2 Reliability

Alternative 1 would not require implementation of active remedial measures; this alternative would, therefore, not present O&M requirements or hazards associated with component failure.

Table 8.14. Summary of Performance Analyses for the X-749/X-120 Area, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative Number and Elapsed Time	Max. TCE Conc. In Gallia (Fg/L)	Area > 5 Fg/L and > 10^{-6} risk (ft^2)	Area > 50 Fg/L and > 10^{-5} risk (ft^2)	Area > 500 Fg/L and > 10^{-4} risk (ft^2)
1 - 10 years	3,310	5,000,000	3,080,000	773,000
1 - 20 years	3,070	5,790,000	3,540,000	513,000
1 - 30 years	2,790	5,720,000	3,560,000	288,000
2 - 10 years	2,410	3,800,000	2,190,000	578,000
2 - 20 years	1,860	4,160,000	2,120,000	373,000
2 - 30 years	1,340	4,060,000	2,070,000	210,000
3 - 5 years	1,020	1,810,000	996,000	194,000
3 - 10 years	627	1,210,000	542,000	272,000
3 - 15 years	342	817,000	237,000	0
3 - 20 years	151	575,000	111,000	0
3 - 25 years	61	359,000	6,600	0
3 - 30 years	43	250,000	0	0
4 - 5 years	1,020	1,810,000	997,000	194,000
4 - 10 years	627	1,210,000	542,000	27,200
4 - 15 years	342	817,000	237,000	0
4 - 20 years	151	575,000	111,000	0
4 - 25 years	74	210,000	6,400	0
4 - 30 years	16	638,000	0	0
5 - 10 years	701	1,340,000	568,000	72,000
5 - 20 years	222	515,000	110,000	0
5 - 30 years	46	273,000	0	0
6 - 10 years	508	2,660,000	830,000	194
6 - 20 years	299	1,640,000	360,000	0
6 - 30 years	91	1,190,000	51,600	0

Alternative 2 uses deed and land use restrictions to prevent exposure to and direct contact with the contaminants. The long-term enforceability and resulting reliability of deed and land use restrictions may be uncertain if the property changes ownership or if enforcement of deed and land use restrictions cannot be assured. Alternative 2 would require operation and maintenance efforts in maintaining the monitoring wells.

Alternatives 3 through 6 all incorporate barrier walls and the existing X-749 southwest groundwater collection trench of the X-749 Landfill to contain contaminants beneath the landfill. Continued effectiveness of these measures in Alternatives 3 through 6 is dependent on the ability of the trench and barrier walls to prevent migration of contaminants from the landfill.

Alternative 3 uses the institutional controls described under Alternative 2 in combination with a system to pump and treat contaminated groundwater. Continued effectiveness of this alternative will depend on the long-term maintenance of the groundwater extraction wells.

Alternative 4 uses institutional controls and extraction wells in combination with phytoremediation. The effectiveness of this alternative is dependent on the ability of extraction wells to reduce contaminant levels during the first 20 years of this scenario to a level that allows trees to contain and reduce contaminant levels during the final 10 years.

Alternative 5 uses hybrid poplar trees as well as the institutional controls described under Alternative 2. The continued effectiveness of this alternative relies on long-term maintenance of the trees.

Alternative 6 uses enhanced bioremediation and hybrid poplar trees in combination to reduce groundwater contamination. The continued effectiveness of this alternative relies on long-term maintenance of the trees.

8.6.1.3 Implementability

All alternatives use off-the-shelf components, manpower requiring limited training, and well-understood operating parameters. Equipment and administrative controls range from those already in place to those taking up to 18 months to fully implement. However, the selected remedy may require modification after implementation if this area is industrialized in the future. The area west of the X-749 Landfill and south of Lewis Street extending to the Perimeter Road has been identified as a possible location of a new UF_6 Tails Conversion Facility, scheduled to be in operation within five years. In addition, construction of a new uranium enrichment facility may take place in this area if PORTS is selected by USEC for this new plant. Alternative 6 would be least impacted by possible reindustrialization projects.

8.6.1.4 Safety

Alternative 1 would pose the fewest safety risks because no significant construction activities are associated with its implementation. Alternatives 3 through 6 pose significantly greater safety risk related to the complexity of construction. These risks, however, are minor and easily mitigated by standard construction practices.

8.6.2 Human Health Analysis

Alternative 1 poses no additional short-term exposure risks to remediation workers, the neighboring population or current onsite workers because no additional remediation activities are conducted. The remaining alternatives involve additional short-term risks to onsite and remediation workers during implementation but do not impact neighboring populations. Alternative 1 increases the long-term risks by eliminating deed and access restrictions. Alternatives 2 through 6 maintain these restrictions and decrease the long-term risks by removing and/or treating a portion of the total contaminant mass and reducing the size of the contaminant plume.

8.6.3 Environmental Analysis

Model simulations for Alternatives 3 through 6 predict that contamination in the X-749/X-120 Area groundwater will not leave the PORTS site. Construction for Alternatives 3 through 6 could initially disrupt ecological receptors but is not expected to result in permanent effects. None of the alternatives would have adverse effects on wetlands, archeological resources, cultural resources, flood elevations or critical habitats. No socioeconomic effects are anticipated from implementation of any of the alternatives.

8.6.4 Institutional Analysis

Alternatives 1 and 2 would not meet RAOs associated with preventing contaminated groundwater from impacting surface water or achieving groundwater PRGs. Alternatives 3 through 6 are predicted to reduce contaminant concentrations to below PRGs where practicable and meet all RAOs.

8.6.5 Cost Analysis

Each alternative's capital and O&M cost is presented in Table 8.15. Table 8.15 also summarizes the results of remedial alternatives for the X-749/X-120 Area.

Table 8.15. Summary of Alternative Analyses for the X-749/X-120 Area, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Alternative	Technical Analysis	Human Health Analysis	Environmental Analysis	Institutional Analysis	Contaminant Plume Summary After 30 years		30 Year Present Worth Costs ($1,000s) Capital/O&M
					Maximum Remaining Concentrations in Gallia (μg/L)	Remaining Area Above PRG (Million ft^2)	
1 - No Action	No implementation is required.	No short-term risk. Long-term exposure to onsite workers.	No risk to environmental indicators.	Does not meet RAOs.	2,790	5.72	0/0
2 - No Further Action	Readily implementable. Deed and land use restrictions would be reliable if site controls are maintained.	No short-term risk.	No risk to environmental indicators.	Does not meet RAOs.	1,340	4.06	0/5,974
3 - Pump and Treat	Readily implementable. Installation of wells will be required.	Short-term risk to remediation workers.	Short-term effect on ecological receptors is minimal.	Meets all RAOs.	43	0.250	2,564/12,749
4 - Pump and Treat with Subsequent Phytoremediation	Readily implementable. Installation of wells and trees will be required.	Short-term risk to remediation workers.	Short-term effect on ecological receptors is minimal.	Meets all RAOs.	16	0.638	2,564/11,623
5 - Phytoremediation	Readily implementable. Installation of trees will be required.	Short-term risk to remediation workers.	Short-term effect on ecological receptors is minimal.	Meets all RAOs.	46	0.273	602/5,433
6 - Enhanced Bioremediation and Phytoremediation	Readily implementable. Installation of trees will be required.	Short-term risk to remediation workers.	Short-term effect on ecological receptors is minimal.	Meets all RAOs.	91	1.19	5,228/10,182

RAOs = Remedial Action Objectives
* At end of simulation

8.7 REFERENCES

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